

## **Geological Disposal Concept Selection Aligned with a Voluntarism Process – 13538**

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### **ABSTRACT**

The UK's Radioactive Waste Management Directorate (RWMD) is currently at a generic stage in its implementation programme. The UK site selection process is a voluntarist process and, as yet, no communities have decided to participate. RWMD has set out a process to describe how a geological disposal concept would be selected for the range of higher activity wastes in the UK inventory, including major steps and decision making points, aligned with the stages of the UK site selection process. A platform of information is being developed on geological disposal concepts at various stages of implementation internationally and, in order to build on international experience, RWMD is developing its approach to technology transfer. The UK has a range of different types of higher activity wastes with different characteristics; therefore a range of geological disposal concepts may be needed. In addition to identifying key aspects for considering the compatibility of different engineered barrier systems for different types of waste, RWMD is developing a methodology to determine minimum separation distances between disposal modules in a co-located geological disposal facility. RWMD's approach to geological disposal concept selection is intended to be flexible, recognising the long term nature of the project. RWMD is also committed to keeping alternative radioactive waste management options under review; an approach has been developed and periodic reviews of alternative options will be published.

### **INTRODUCTION**

The UK Government has published a framework for managing higher activity radioactive waste in the long-term through geological disposal, coupled with safe and secure interim storage and ongoing research and development to support its optimised implementation. This is a voluntarism process.

The UK Government identified the Nuclear Decommissioning Authority (NDA) as the organisation responsible for implementing its policy on managing higher activity radioactive waste. The NDA has, in turn, established the Radioactive Waste Management Directorate (RWMD) to develop and implement a safe, sustainable and publicly acceptable approach to geological disposal.

As the implementing organisation NDA RWMD has developed a geological disposal concept selection process. The purpose of the process is to select a geological disposal concept for UK higher activity wastes from the range of possible options available. The process has been developed in a number of steps to align with stages in the UK's site selection process.

NDA RWMD has defined a geological disposal concept as an engineered barrier system, and its geometry, required to deliver the safety functions and requirements defined in the disposal system specification, in a particular geological environment. A geological disposal concept is developed for a particular inventory or a particular type of waste, and geological setting. The exact nature of the engineered barrier system, and the safety functions associated with each barrier, will be determined by the wastes being disposed and the geological environment.

The UK has a range of different types of higher activity wastes with different characteristics; therefore a range of geological disposal concepts may be needed. The higher activity waste to be managed in the long term through geological disposal includes High Level Waste (HLW), Intermediate Level Waste (ILW), Low Level Waste (LLW) that cannot be managed at the national LLW Repository, and materials such as Spent Fuel, Plutonium and Uranium. The UK Government sees no case for having separate facilities if one facility can be developed to provide suitable, safe containment for the higher activity waste inventory. This is because the sharing of surface facilities, access tunnels, construction



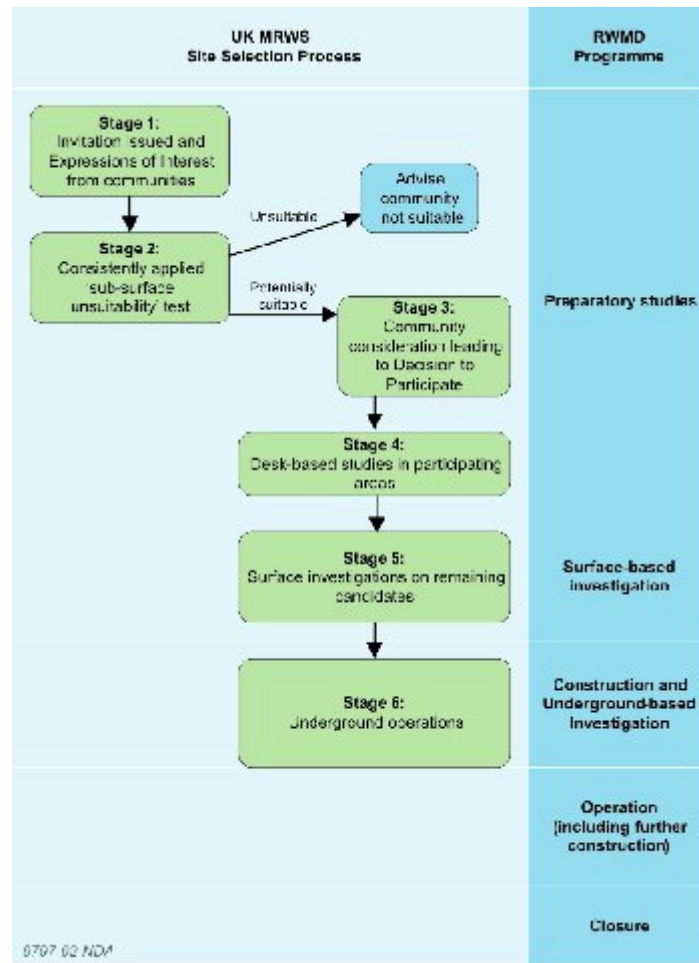


Fig. 2. Phases in the programme for implementing geological disposal showing how they relate to the stages of the Managing Radioactive Waste Safely site selection process.

Figure 2 sets out the stages in the MRWS site selection process aligned with NDA RWMD’s programme for implementing geological disposal. These stages provide the key decision making points where regulatory permits, licenses and permissions may be required.

At these stages, decisions on the selection of geological disposal concepts will be taken. Geological disposal concepts will need to be selected to support the assessments that will be used in the preparation of regulatory submissions. The range of potentially suitable geological disposal concepts will be used in assessments to illustrate the scope of potential assessment results.

The selection of disposal concepts for all purposes within the process will be supported by a structured analysis of available options. The attributes to be applied during geological disposal concept selection includes a range of safety, environmental, technical, social, economic, ethical, and security factors. Initially the selections will be preliminary choices, and through iterative development of the disposal system and improved understanding of sites, the preferred options will be identified.

### Description of Steps in the Concept Selection Process

The concept selection process has been structured in line with information expected to be available and required at different stages of the site selection process.

The process comprises four key aspects:

- Maintenance of a range of geological disposal concepts and progressive screening of these concepts to identify those that remain viable;
- Selection of a geological disposal concept for UK higher activity wastes for each potential candidate site to be used as a basis for desk based studies and strategic environmental assessment;
- Selection of a geological disposal concept for UK higher activity wastes for each candidate site to serve as the basis for initial site evaluations;
- Selection of a geological disposal concept for UK higher activity wastes to serve as the basis for a preliminary environmental safety evaluation, environmental impact assessment, and an initial pre-construction safety report.

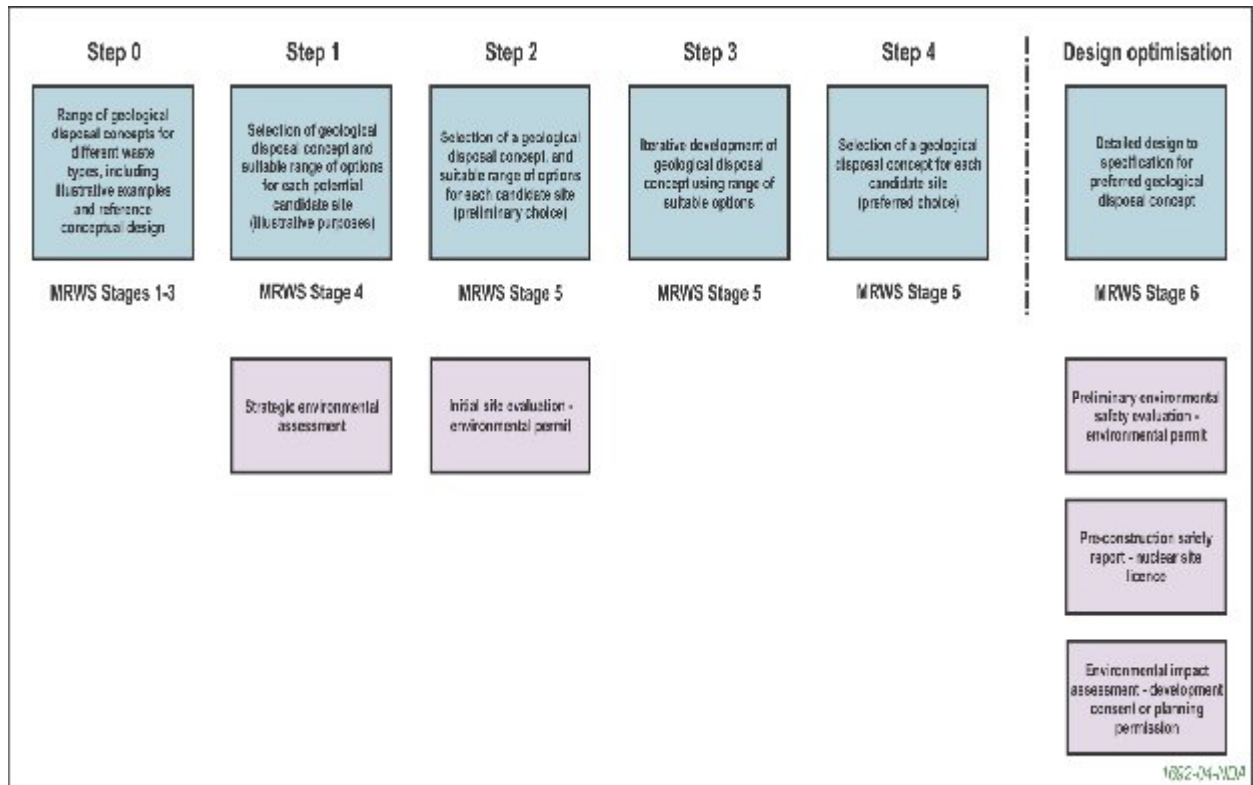


Fig. 3. The Concept Selection Process.

At step 1, during MRWS Stage 4 a geological disposal concept for the UK higher activity wastes will be selected for each potential candidate site, to be used as a basis for desk based studies and strategic environmental assessment. Criteria for site identification and assessment have been set out to support desk based studies [3]; these criteria will be further developed with local stakeholders in volunteer communities. Geological disposal concepts will be used to provide information on a range of parameters that would underpin the assessment criteria, such as, the feasibility of developing a robust safety case, the possible size and nature of underground layouts, the complexity of the potential underground development and the relative ease of implementation. The range of geological disposal concepts that could be suitable at each potential candidate site will be used to scope the potential impacts.

At step 2, early in MRWS Stage 5 a geological disposal concept for UK higher activity wastes will be selected for each candidate site to serve as the basis for initial site evaluations. These geological disposal concepts will be considered preliminary and will be reviewed and revised, based on improved site understanding and feedback from iterative development of the disposal system.

Step 3 continues throughout MRWS Stage 5, as geological disposal concepts will be reviewed to evaluate their compatibility with the site data, and revised based on improved site understanding and feedback from iterative development of the disposal system. It is not the intention of the concept selection process to design around problems at a site that is fundamentally unsuitable. However, for some sites it may be possible to compensate for certain geological or hydrogeological conditions through the selection of concepts, design or layout of a geological disposal facility.

Step 4 will occur by the end of MRWS Stage 5, when a geological disposal concept for UK higher activity waste will be selected to serve as the basis for a preliminary environmental safety evaluation, environmental impact assessment, and an initial pre-construction safety report. The geological disposal concept selected for each candidate site will be the preferred option based on the knowledge and understanding accumulated by the end of MRWS Stage 5.

The preferred geological disposal concept for UK higher activity wastes will be taken forward, further developed and modified as required through design optimisation, taking into account further site specific information, research and development and waste characterisation. Information on alternative geological disposal concepts will be held to provide flexibility; recognising that at the start of underground operations uncertainty will remain regarding conditions underground, and there may still be a need to move to a different geological disposal concept if conditions are significantly different from those predicted from the results of surface based investigations.

### **Managing Uncertainty in the Generic and Early Site Specific Stages**

At present no site has been selected to host a geological disposal facility and the Government's Department of Energy and Climate Change are leading on the site selection process. There is uncertainty in a number of areas, including, the inventory to be disposed of, the geological setting, and the geological disposal concepts that could be selected.

In order to manage this uncertainty NDA RWMD has developed a reference case inventory and an upper inventory; defined three generic geological settings and a range of geological disposal concepts to be considered.

As the process progresses, the number of geological disposal concept options (and possible number of different host rocks or target horizons) under consideration will become progressively fewer and their level of detail greater. Narrowing of options does not imply that other geological disposal concepts are permanently removed from future consideration. Options not taken forward would be reconsidered should there be changes to the information upon which decisions were made. There is also the possibility that new options are introduced later in the programme (e.g. due to new technology development). Decisions on geological disposal concepts are subject to review until implementation is initiated and, even then, review to introduce improvements is not precluded. Review of decisions requires traceable recording of the information and assumptions on which the decision-making was based throughout the process.

The process aims to be both flexible and pragmatic by selecting geological disposal concepts, supported by a range of options. We aim to ensure flexibility in our approach by keeping information on a range of geological disposal concept options available and up to date. However, in order to have a manageable programme of work, a geological disposal concept for UK higher activity wastes will be selected as the basis of assessments, around which the effects or impacts of selecting different geological disposal concepts can be compared.

The inventory of higher activity wastes to be disposed of will also develop during the MRWS Stages. Inventory uncertainties will be taken into account by considering the implications of different inventories on the selection of different geological disposal concepts.

## **Information on Geological Disposal Concepts based on International and UK Experience**

To support the selection of geological disposal concepts at various stages of the process, a range of geological disposal concept options has been identified. RWMD has gathered information on geological disposal concepts for the disposal of Low and Intermediate Level Waste, High Level Waste and Spent Fuel, Uranium and Plutonium [4, 5, 6]. The information is based on experience of geological disposal concepts developed in the UK and internationally.

In the work carried out to date RWMD has identified geological disposal concepts for groups of waste individually. Since a geological disposal concept for UK higher activity wastes will include a number of compatible geological disposal concepts for each group or type of waste, the next step is to consider the compatibility of disposal concepts for different types of waste.

### *An Integrated Disposal System*

Before considering integration of disposal concepts, each set of waste-specific disposal concepts was grouped according to their key generic characteristics, based on a consideration of the utilisation of the available space within a potential host rock and by the operational procedures required for implementation. All of the generic geological disposal concepts are considered to be safe given certain assumed programme scenarios, and, therefore, transport, operational and post-closure safety is also implicitly accounted for in each of the groups of disposal concepts.

Five groups of generic HLW and spent fuel geological disposal concepts were identified:

- In-tunnel Borehole concepts.
- In-tunnel Axial concepts.
- Supercontainer concepts.
- Cavern-based concepts.
- Mined Borehole Matrix concepts.

Two groups of generic ILW/LLW geological disposal concepts were identified:

- Vault-based concepts.
- Silo-based concepts.

Ten generic integrated concepts were then identified by combining the waste specific disposal concepts. At this stage in the programme, when engineering issues have not been explicitly addressed during the identification of uranium and plutonium disposal concepts, it has been assumed that depleted, natural and low-enriched uranium (DNLEU) will be disposed of using a disposal concept for ILW/LLW, and high-enriched uranium (HEU) and plutonium will be disposed of using a concept for HLW and spent fuel. This is a simplifying assumption at this stage, and the optimised disposal concept may incorporate more than two disposal concepts. Furthermore, the selection of the disposal concept will be based on an analysis of site-specific requirements and may combine elements of the different disposal concepts recognised to date.

For each of the ten generic geological disposal concepts, estimates have been made of some key metrics that could be used during Stage 4 of the MRWS site selection process e.g. underground footprint, excavated spoil volume and the requirement for engineered barrier materials. These are based on existing RWMD information, and have been developed for each generic host rock (higher strength rocks, lower strength sedimentary rocks and evaporites), and for two different inventory scenarios.

The compatibility of the two disposal concepts making up each integrated concept was then considered. The ability to co-locate disposal modules based on different disposal concepts is dependent on the extent to which interactions might occur between the two types of disposal module. Key thermal, hydrogeological, mechanical, chemical and gas interactions, and interactions resulting from operational constraints and programme decisions were identified and used to assess the

compatibility of the two disposal concepts making up each of the ten integrated concepts. At the current stage of programme implementation, none of the ten integrated concepts contain any fundamental incompatibility that should exclude them from further consideration.

The strengths and weaknesses introduced by combining HLW and spent fuel disposal concepts with ILW disposal concepts, into integrated disposal concepts were considered. It was concluded that strengths and weaknesses of overall integrated disposal concepts are likely to be less important in disposal concept selection than the strengths and weaknesses inherent in the individual waste-specific disposal concepts themselves, unless sites with a limited volume of host rock are available. However, the consideration of strengths and weaknesses of integrated disposal concepts will provide an input to the selection of disposal concepts for each module of the geological disposal facility, which is likely to include the use of specific concepts for specific types of waste. The significance of any strengths and weaknesses is likely to be a site specific consideration.

### *Co-location of Geological Disposal Concepts*

RWMD's generic disposal system specification [7] contains a requirement that potential thermal, mechanical, hydrogeological and chemical interactions and the potential for migration of geological disposal facility-derived gas shall be taken into account when determining the separation distance between disposal modules for different waste categories, and the design of a geological disposal facility shall ensure that interactions between one disposal module and another will not compromise the performance of the disposal system. These interactions are site specific and disposal concept specific and will need to be taken into account in the design process.

RWMD is developing a methodology to determine the minimum separation distance between disposal modules in a GDF. The methodology will be applied first during site identification in Stage 4 of the MRWS site selection process, but will be suitable for use at all stages of implementation. The thermal, hydrogeological, mechanical, chemical and gas (THMCG) processes that may cause interactions between disposal modules and that will need to be considered within the methodology have been described to provide a knowledge base that will underpin development of the methodology. The methodology to determine the minimum separation distance will:

- Incorporate a consideration of the post-closure THMCG interactions that could potentially occur in between disposal modules.
- Focus on the key interactions that could potentially occur.
- Be consistent with the broader RWMD programme and be informed by a consideration of the generic geological environments.
- Incorporate the ability for the significance of any interaction to be judged at the time the methodology is applied.
- Consider the relative timing of engineered barrier system emplacement and the date for final closure of a geological disposal facility.

In practice, the design of a geological disposal facility could incorporate a separation distance significantly larger than the minimum distance, for example to incorporate specific design features.

### *Technology Transfer*

The information platform being developed and maintained by RWMD to support geological disposal concept selection could be enhanced by the transfer of technology from overseas programmes that are more advanced. Opportunities for transferring technology from other waste management organisations are being investigated. RWMD is developing its strategy and approach for technology transfer, including identifying the appropriate steps in the concept selection process for knowledge, technology and design insertion points. Technology transfer is intended to build on knowledge and experience developed internationally, in addition, analysing and learning from safety submissions prepared by other waste management organisations could potentially reduce timescales and costs of geological disposal implementation in the UK.

The level of development, understanding and demonstration of different geological disposal concepts will be a consideration in geological disposal concept selection. The applicability of work undertaken in other countries to the UK situation is a key factor in work on technology transfer. The development of a geological disposal concept for UK higher activity wastes will need to make use of international best practice and apply this in the UK context (e.g. taking into account different stakeholder requirements, and a different inventory) to the conceptual understanding of the geological environments made available through site selection. Technology transfer studies will add to the platform of information provided to support the decision making steps set out in the concept selection process.

## **INTERACTIONS WITH THE UK NUCLEAR INDUSTRY**

### **NDA Strategy Development**

The objective of the NDA's higher activity waste strategy is to treat and package retrieved higher activity waste and place it in safe, secure and suitable storage facilities until it can be disposed of, or be held in long term storage in the case of a proportion of higher activity waste in Scotland. Strategic decisions about waste management are informed by the following key principles:

- Risk reduction is a priority
- Centralized and multi site approaches should be considered where it may be advantageous
- Waste should be minimized
- The waste hierarchy should be used as a framework for waste management decision making and enables an effective balance of priorities including value for money, affordability, technical maturity and the protection of health, safety, security and the environment.

RWMD supports NDA strategy development, providing information to support development and selection of credible and preferred options for the lifecycle management of higher activity radioactive wastes. RWMD provide information on disposal options and NDA provide information to RWMD on lifecycle management issues for higher activity radioactive waste to ensure these are factored into the RWMD geological disposal concept selection process.

RWMD manages a programme of option studies to expand its knowledge base on particular aspects of geological disposal concepts, and to better understand the implications of novel concepts and specific waste packaging options. These option studies are influenced by RWMD information needs and the needs of NDA strategy development. RWMD provide input to NDA option studies and strategic studies to inform long term management of wastes.

### **Waste Packaging**

An important input to geological disposal concept development is the waste that is currently being packaged in the UK. The NDA RWMD interacts with waste packaging organisations by providing standards and specifications for waste packaging. These specifications are generic and are based on a range of geological disposal concepts considered in other countries. The geological disposal concept selection process will take into consideration waste that has been packaged in accordance with NDA RWMD's generic waste package specifications.

Disposal concepts provide the information against which to carry out assessments of disposability of waste packages. Disposability assessments provide information on the latest understanding of wasteform and waste containers likely to be used by waste producers. Through this interaction information and research needs are identified.

The introduction of innovative approaches to waste treatment and packaging may introduce additional complexity into the disposal system to be implemented by RWMD. Therefore, RWMD are implementing procedures to ensure that the complexity potentially introduced by innovative packaging proposals is assessed and managed.



The overall impact on disposal system performance from innovative packaging proposals will need to be evaluated and any resultant constraints on future flexibility considered.

### **Upstream Optioneering**

RWMD has initiated a project called 'upstream optioneering'; this work supports the RWMD objective to identify and deliver solutions to optimise the management of higher activity waste. RWMD undertakes this work in conjunction with waste producers. RWMD refers to this project as 'upstream' because it includes waste management activities up to and including geological disposal. Improvements in the management of higher activity waste could lead to quicker and more cost effective hazard reduction, reduced environmental and safety impacts, and other benefits. The range of generic geological disposal concepts provides the scope of available disposal options to inform upstream optioneering studies. The output of upstream optioneering studies feed back into concept development by providing information on optimised waste packaging solutions that will need to be accommodated by the remaining engineered barriers and geological environment.

### **REVIEW OF ALTERNATIVES TO GEOLOGICAL DISPOSAL**

Implementation of geological disposal is a long-term project and hence it is recognised that an appropriately flexible approach is needed. The commitment to ensuring flexibility in decision making needs to leave open the possibility that other long-term management options could emerge as practical alternatives. Therefore, whilst Government policy is to pursue the geological disposal of higher activity radioactive waste, there is also a need to take account of developments in storage and disposal options, as well as possible new technologies and solutions.

RWMD keeps developments in alternative waste management options under review in order to take developments in storage, disposal and waste treatment options into account in its work programme [8].

The scope of RWMD's review of potential alternative radioactive waste management options is set out below; it comprises:

- Alternative steps in long term management
  - Long-term interim storage options
  - Waste treatment techniques (e.g. partitioning and transmutation).
- Alternatives to geological disposal for certain wastes
  - Near-surface disposal (tens of metres to around 150 metres deep) for short lived waste.
  - Deep borehole disposal.

The review addresses the following aspects:

- Identification and explanation of recent relevant developments in radioactive waste management options.
- Explanation of the significance of these developments for the inventory of higher activity waste.
- Discussion of any developments that merit more detailed attention.

Findings from the review will be published periodically and information will be passed on to Government about any options that merit more detailed attention.

The most recent review of alternative waste management options has not identified any alternative options that could replace geological disposal as a solution for the long term management of all UK higher activity waste. A number of treatment and disposal options could potentially be applied to

certain higher activity wastes, and these developing areas will be kept under review. These include near-surface disposal of shorter-lived wastes and deep borehole disposal.

## CONCLUSIONS

RWMD is currently at a generic stage in its implementation programme. The site selection process is a voluntarist process and, as yet, no communities have decided to participate. RWMD has therefore set out a process to describe how a geological disposal concept would be selected for the range of higher activity wastes in the UK inventory, including major steps and decision making points, aligned with the stages of the site selection process. This process has been published in order to provide information to stakeholders and gain feedback on the proposed approach.

In support of the geological disposal concept selection process RWMD has gathered a platform of information on geological disposal concepts at various stages of implementation internationally. Simplified generic disposal concepts have been described to enable key considerations for integrating different disposal concepts to be identified. In addition to identifying key aspects for considering the compatibility of different engineered barrier systems for different types of waste, RWMD is developing a methodology to determine minimum separation distances between disposal modules in a co-located geological disposal facility. This methodology is intended to be applied during site specific stages of the site selection process.

Other factors that need to be considered as part of the geological disposal concept selection process include the interaction between developing disposal concept options and strategies for the lifecycle management of higher activity waste. There is also waste that is currently being packaged according to RWMD specifications and standards to be disposed in a geological disposal facility. The UK nuclear industry is encouraged to innovate and develop new solutions to waste management. This has potential to lead to significant complexity in the disposal system, particularly considering the long timescale of geological disposal facility implementation.

In order to build on international experience RWMD is developing its approach to technology transfer; as a first step, identifying the technology developed overseas that could be applicable to the UK situation. Technology transfer studies will add to the platform of information provided to support the decision making steps set out in the concept selection process.

Implementation of geological disposal is a long-term project and hence it is recognised that an appropriately flexible approach is needed. RWMD is committed to keeping alternative radioactive waste management options under review. An approach has been developed and periodic reviews of alternative options will be published.

The concept selection process aims to be both flexible and pragmatic by selecting geological disposal concepts, supported by a range of options, for each key decision making step. Flexibility is provided by keeping information on a range of geological disposal concept options available and up to date.

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